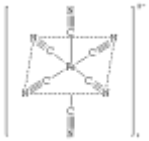
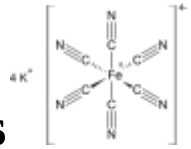


# Colorful Iron Complexes



The chemistry of iron (Fe) is dominated by the +2 and +3 oxidation states; iron(II), $Fe^{2+}$ and iron(III), $Fe^{3+}$complexes and complex ions with selected ligands (attached ion or functional group). These groups usually are of an octahedral shape, a few tetrahedral iron(III) complexes are mentioned too. The reactions of the aqueous ions iron(II) and iron(III) with the cyanide ion will be explored in this lab.

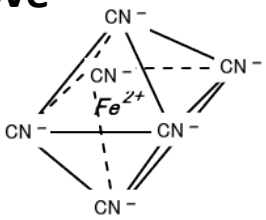
**Data Chart:**
Use an entire page to copy the following table in "landscape" orientation.
You will fill out the cells as you complete the lab.

| Test Tube | Solution #1 (Name and Formula) | Oxidation # of Iron | Solution #2 (Name and Formula | Oxidation # of Iron | Observations | Reaction(s) |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |

**Procedures:**
1. Place six test tubes in a test tube rack.
Label the tubes 1–6 and then label tubes 1–3 as $Fe^{2+}$and tubes 4–6 as $Fe^{3+}$. Use masking tape for this.

2. Add approximately 7 mL of 0.02 M iron(II) sulfate solution and 7 mL of distilled or deionized water to test tubes 1–3.
Stopper the tubes and swirl to mix

3. Add approximately 7 mL of 0.02 M iron(III) chloride solution and 7 mL of distilled or deionized water to test tubes 4–6.
Stopper the tubes and swirl to mix.




**Part A. Ferrocyanide ions, $Fe(CN)_6^{4-}$ [Iron in the +2 oxidation state]**

4. Add 5 drops of 0.1 M potassium ferrocyanide solution to *Tube 1*. Since both sources of iron are in the +2 state, the notable deep-blue precipitate does not form. Instead a light blue precipitate of potassium iron(II) hexacyanoferrate(II), $K_2Fe[Fe(CN)_6]$, forms according to Equation 1.

$$Fe^{2+} + 2K^{+} + [Fe(CN)_6]^{4-} \rightarrow K_2Fe[Fe(CN)_6](s) \qquad \text{Equation 1}$$

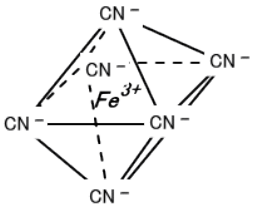
Light blue ppt

5. Add 5 drops of 0.1 M potassium ferrocyanide solution to *Tube 4*. A deep-blue precipitate will form according to equation 2, due to the presence of both iron(II) and iron(III) ions. This resulting deep blue precipitate is iron(III) hexacyanoferrate(II), $Fe_4[Fe(CN)_6]_3$, or Prussian blue.
Determine the oxidation number of each iron atom in the complexes in Equations 1 and 2.

$$4Fe^{3+} + 3[Fe(CN)_6]^{4-} \rightarrow Fe_4[Fe(CN)_6]_3 \qquad \text{Equation 2}$$

Prussian blue

Upon standing for 5–10 minutes, the solution in Tube 1 will turn darker blue as the iron(II) is slowly oxidized to iron(III) by atmospheric oxygen to form the same Prussian blue precipitate as in equation 2.




**Part B. Ferricyanide ions, $Fe(CN)_6^{3-}$ [Iron in the +3 oxidation state]**

6. Add 5 drops of 0.1 M potassium ferricyanide solution to *Tube 2*. A deep-blue precipitate will form with the iron(III) sulfate. In this reaction, the ferricyanide ions, $[Fe(CN)_6]^{3-}$, oxidize iron(II) to iron(III) forming ferrocyanide ions, $[Fe(CN)_6]^{4-}$, according to Equation 3:

$$Fe^{2+} + [Fe(CN)_6]^{3-} \rightarrow Fe^{3+} + [Fe(CN)_6]^{4-} \qquad \text{Equation 3}$$

$$4Fe^{3+} + 3[Fe(CN)_6]^{4-} \rightarrow Fe_4[Fe(CN)_6]_3$$

The products of equation 3, the iron(III) ions and ferrocyanide ions, then combine to form iron(III) hexacyanoferrate(II) or Prussian blue, according to equation 2 above.

7. Add 5 drops of 0.1 M potassium ferricyanide solution to *Tube 5*. A brown solution is observed, indicating no reaction since both iron sources are in the +3 oxidation state, as shown below:

$$Fe^{3+} + [Fe(CN)_6]^{3-} \rightarrow \text{No Reaction}$$

**Part C. Thiocyanate ions, $SCN^-$**

8. Add 5 drops of 0.1 M potassium thiocyanate solution to *Tube 3*. Some light red-brown coloring may appear due to slight oxidation of $Fe^{2+}$ to $Fe^{3+}$, but no visible reaction is observed.

$$Fe^{2+} + 3SCN^- \rightarrow \text{No Reaction}$$

9. Add 5 drops of 0.1 M potassium thiocyanate solution to *Tube 6*. A deep-red complex will form with the iron(III) sample according to Equation 4. This is a positive indicator test for the iron(III) ion.

$$Fe^{3+} + 3SCN^- \rightarrow Fe(SCN)_3 \qquad \text{Equation 4}$$

Blood-red complex

**Clean up:**

All solutions should be disposed of in the $Fe(XCN)_6^{x}$ waste beaker in the hood and then test tubes washed out in the sink with soap and water.
Remove all labels as well.

**Post Lab Questions:**

1. Propose a reason for the appearance of the different colors you observed based on previous knowledge you have. The reason does not have to be exactly right but should make since in its self.

2. What is the name of each of the following compounds?

| | | | | |
|---|---|---|---|---|
| NaF | $H_2S$ | $CCl_4$ | $FeCl_3$ | $Mg(OH)_2$ |
| $NH_4Br$ | $XeF_4$ | $ZnCl_2$ | $Ca_3(PO_4)_2$ | $Na_3N$ |

3. What is the charge of the anion, if present, in the compound from question 2?

4. How many atoms of each element are in the following compounds?

$Ca_3(PO_4)_2$ $(NH_4)_2S$ $Ca(C_2H_3O_2)_2$

5. What is the oxidation number ***and*** name of the following transition metals in each ion/ compound?

Ex. $[Fe(CN)_6]^{4-}$ iron (Fe) is the transition metal and the oxidation state is as follow:

| | |
|---|---|
| Total charge -4,<br>6 CN ions that are -1 each<br>1Fe ion that is ? charge | 1(?) + 6(-1) = -4<br>$Fe^x$ $CN^-$<br>So Fe is +2 or **iron (II)** |

a. $[Mn(H_2O)]^{2+}$ b. $[Cr(O)_4]^{3-}$ c. $IrCl_3$

d. $Rb_3[Fe(CN)_6]_8$ e. $Tc(PO_4)_2$ f. $[Pd(Cl)_4]^{2-}$

g. $[Au(Cl)_4]^-$ h. $[Ni(CN)_5]^{3-}$ i. $[Mo(CN)_8]^{3-}$

6. In test tube #2, the following reaction was observed:. This reaction continued as:

____$Fe^{3+}$ + ____$[Fe(CN)_6]^{4-} \rightarrow$ ___$Fe_4[Fe(CN)_6]_3$.

If the subscripts distribute into the parenthesis to denote the number of atoms, what coefficients would you need to place in front of each compound to make sure that there are the same number of each atom on either side of the equations (right and left of arrow)?

Ex. _1_$Pb(NO_3)_2(aq)$ + _2_$KI(aq) \rightarrow$ _2_$KNO_3(aq)$ + _1_$PbI_2(aq)$

1 Pb on each side

2 N on each side

6 O on each side

2 K and 2 I on each side.

Trial and error is how you determine the coefficients to use.

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